Superconducting Magnet Division

Magnet Note

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Title: Evaluation of SonicBond Prepreg in Slotted Windings

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Evaluation of SonicBond Prepreg in Slotted Windings

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As part of LDRD 03-013, Proposal for Niobium/Tin Superconducting Magnet, prepreg material ("prepreg" is jargon for fiberglass cloth filled with B-stage epoxy, epoxy that is semi-cured when used in putting together a magnet) was obtained from Fraivillig Technologies Company (FTC) to evaluate improved anchoring of the windings in slotted coil magnets. Coils made to date with NbTi have been generally successful, but examination of cross sections in various windings that have been autopsied indicates that improvements could be made. In particular, it has been noticed that the windings sometimes have too little epoxy, which may lead to conductor movement and premature quenching. In addition, the material used to date is a pure epoxy without filler. Such epoxy is known to have little strength in large volumes. In parts of the coil that have larger volumes of this material, this may lead to cracking under the cryogenic and Lorentz forces. Such cracking may be avoided with an epoxy that has a ceramic filler material. This question gains importance in the higher field magnets that are being pursued using Nb_3Sn superconductor.

A series of six panels with varying compositions of epoxy, named *SonicBond* panels, was prepared by FTC for evaluation at BNL. The properties of the panels are listed in Table I. To evaluate this material, in particular the thickness of a winding that results from its use, but also its ability to fill voids, sample sections that simulated actual windings were prepared by L. Welcome. Several of the sections are shown in Fig. 1. During preparation and after completion, these sections were measured and visually examined. The results are shown in Table II along with the results for a "Standard" section made with the materials that have been used for the RHIC Snakes and currently being used for the AGS Snake.

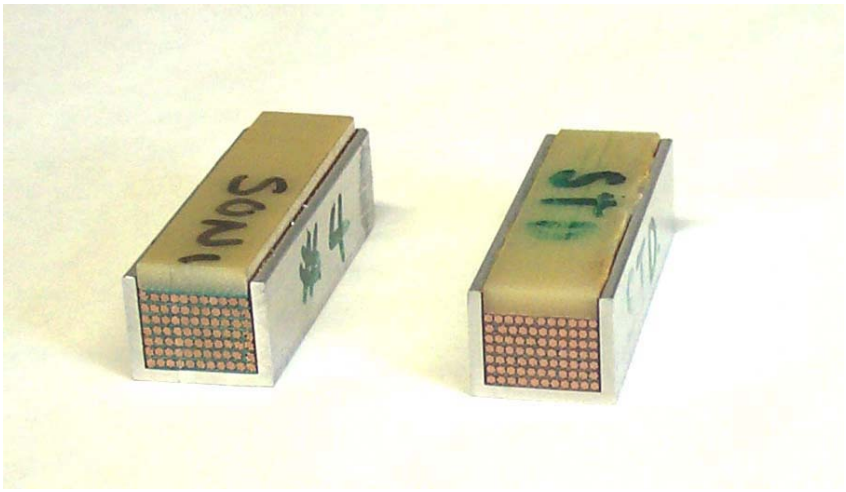

Figure 1 Several sections of the test samples.

All the materials appear to fill the volumes with adequate amounts of epoxy. Examination of the samples shows that the added epoxy from these samples gives the desired additional epoxy in the windings without excessive amounts of material flowing out of the cavities during the cure. The price is some additional thickness per layer. The sample favored from this study, sample #4, has a

post cure thickness of 9 mils per layer, compared to the current standard of 5.3 mils per layer. In a 9 layer winding, which would have 10 layers of prepreg, this would give an additional stack thickness of 37 mils, an amount that is tolerable in building these coils.

An enlarged photo of one of the sections of sample # 4, the preferred sample from this study, is shown in Fig. 2.

Figure 2 Photo of a section of Sample 4.

It is expected that this combination of epoxy and prepreg will give improved performance in slotted coil magnets. The improved performance will come from the ceramic filler in the epoxy, which will strengthen it, and from the increased amount of epoxy, which will reduce the chances for voids in the finished matrix. No test was made of the cryogenic properties of this formulation in this series of tests, but experience with this epoxy in other projects has demonstrated its suitability. We expect to use this material in some future windings for further evaluation.

Table 1 List of SonicBond Prepreg Panels

FRAIVILLIG TECHNOLOGIES COMPANY
98 Charles Street #1
Boston, MA 02114
Phone 512-784-5698
Fax 508-462-0706
www.fraivillig.com

November 4, 2003

To: **Erich Willen**
Brookhaven National Lab

CC: BNL Procurement

From: Jim Fraivillig

BNL P.O. #75683: Description and comments on ***SonicBond*** prototype panels

The box of SonicBond prototype panels have been sent through BNL Receiving (Bldg 100) to your attention (approx. dimensions: 20-22" x 32-34"). The following types are included:

SonicBond prototype construction

Labeled	Description (lamination stack-up, face-up in box)	Panels	Thickness (approx)	Inorganic components By weight	By volume
1	PSA / unfilled adhesive / CORE / unfilled adhesive / PSA	2	17	29%	16%
1A	PSA / unfilled adhesive / CORE / unfilled adhesive x 2 / PSA	1	20	25%	14%
2	PSA / unfilled adhesive x 2 / CORE / unfilled adhesive / PSA	1	~~17~~ 20	29%	16%
3	PSA / unfilled adhesive / CORE / FILLED adhesive / PSA	2	19	39%	23%
4	PSA / FILLED adhesive / CORE / FILLED adhesive / PSA	2	21	47%	29%
5	PSA / FILLED adhesive x 2 / CORE / PSA	1	21	47%	29%

NOTE:

- KEEP SONICBOND PANELS IN FREEZER TO PREVENT ADHESIVE CROSS-LINKING.
- Description of lamination components, with approximate thicknesses: CORE = 7-mil composite of fiberglass cloth+unfilled adhesive (construction is unbalanced -- adhesive is mostly on 'top side' due to coating method); unfilled adhesive sheet = 3 mil; FILLED adhesive sheet = 5 mil of 50%-by-weight alumina powder (pigmented blue); PSA = 2 mil 3M acrylic.
- Constructions have varied inorganic content (ceramic + glass, vs. polymer adhesives). As ceramic and glass are denser than polymers, the amount of inorganic is lower on a volume scale than on a weight scale.
- Constructions have varied layer lamination placement: #1: equal amounts of unfilled adhesive, above and below CORE; #1A: more adhesive below CORE; #2: more adhesive above CORE; #3: unfilled adhesive 'up', where wires will be bonded, and FILLED adhesive down; #4: equal amounts of FILLED adhesive, above and below CORE; #5: all FILLED adhesive above CORE; only PSA below the CORE.
- The cosmetic quality of some of these laminates is poor –*it is very hard to get good quality without continuous lamination process equipment*––but the panels should be sufficient to run evaluation tests.

Table II *Test Results for Various Fraivillig Prepreg Materials*

Tests done in aluminum channels about 6" long, slots 7/16" wide, 1/2" deep, wall thickness 0.062"
Samples made with the new prepreg and standard 0.043" cable, 11 turns per layer, 7 layers, using ultrasonic gun to seat layers into prepreg
Press plate on top: 1/8" thick
Total thickness of AL wall, cable and press plate: 0.488"
Cure for new material: 1 1/2 hrs @ 175 C ("standard" material currently used 2 1/2 hrs @ 121 C)
Pressure applied during cure: 25# lead brick on ~3 sq in = ~8#/sq in
After cure, each sample cut into 3 pieces to allow examination of the cross section of each package

Stackup Thickness of Materials Received from Fraivillig, mils

Sample	PSA	Adhesive	Core	Adhesive	PSA	Total
1	2	3	7	3	2	17
1a	2	3	7	6	2	20
2	2	6	7	3	2	20
3	2	3	7	5	2	19
4	2	5	7	5	2	21
5	2	10	7	0	2	21
Standard	2	0	13	0	2	17

Notes:

Adhesive of 3 mils is unfilled prepreg, 6 mils is a double layer
Adhesive of 5 mils is filled prepreg, 10 mils is a double layer
Core is fiberglass cloth plus unfilled adhesive, PSA is pressure sensitive 3M acrylic

Thickness Test Results

	Package, in			Per Layer, mils	
Sample	Thk pre-cure	Thk post-cure	Stackup thk pre-cure	Actual thk pre-cure	Actual thk post-cure
1	0.572	0.541	0.624	10.5	6.6
1a	0.592	0.552	0.648	13.0	8.0
2	0.575	0.540	0.648	10.9	6.5
3	0.600	0.550	0.640	14.0	7.8
4	0.607	0.560	0.656	14.9	9.0
5	0.603	0.573	0.656	14.4	10.6
Standard	0.560	0.530	0.624	9.0	5.3
	measured				

Summary, Sample Thickness per Layer

Sample	Stackup	Pre-cure	Post-cure
1	17	10.5	6.6
1a	20	13.0	8.0
2	20	10.9	6.5
3	19	14.0	7.8
4	21	14.9	9.0
5	21	14.4	10.6
Standard	17	9.0	5.3